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ENGINEERING PROPERTIES OF SELECTED GROUNDNUT (ARACHIS HYPOGEA L.) VARIETIES

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ABSTRACT

Engineering properties of groundnut pods play an essential role in designing of threshing equipment, in order to decide the cylinder speed, concave clearance, sieve sizes and seed drop mechanisms. The present study aimed to determine the engineering properties of pods of six groundnut varieties viz., ICGV-00351, KADARI-9, R-8808, R-2001-2,

R-2001-3 and TMV-2. The results revealed that, the computed mean value of roundness and perimeter were found to be 0.72 and 78.53 mm, respectively. The sphericity and surface area of all the varieties were in the rage of 0.62 to 0.71 and 605.26 to 778.43 mm2 with a mean value of 0.66 and 692.69 mm2, respectively. The geometric mean, arithmetic mean, square mean and equivalent diameter were found to be 14.82, 15.89, 22.13 and 17.62 mm, respectively with an average bulk density of 0.26 g cm-3. The mean value of pod-vine ratio for six groundnut varieties was found to be 3.59. The groundnut pods were neither round nor spherical, but oblong in shape. It was observed that, the mean value of force required to detach the pod from vine was found to be 4.28 kg. The terminal velocity of groundnut pod and vine were found to be 8.73 and 3.91 m s-1, respectively. The angle of repose of groundnut pods ranged from 26.36° for TMV-2 to 29.09° for R-8808. The mean values of coefficient of friction of the selected varieties of groundnut pods on plywood, MS sheet and wood were found to be 0.559, 0.406 and 0.623, respectively.

KEYWORDS: Arithmetic Mean Diameter, Coefficient of Friction, Geometric Mean Diameter, Groundnut and Terminal Velocity

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Original Article

INTRODUCTION

Groundnut (Arachis hypogea L.) is called as the 'King' of oilseeds and is one of the most important cash crops, which is a low priced commodity, but a valuable source of all the nutrients. Groundnut is also called as wonder nut and poor men's cashew nut. It is the sixth most important oilseed crop in the world. It contains 48-50 per cent of oil and 26-28 per cent of protein and is rich source of dietary fiber, minerals and vitamins. The world wide groundnut is grown in 26.4 million hectares with a total production of 37.1 million metric tonnes and an average productivity of 1.4 metric tonnes per ha. Developing countries constitute 97 per cent of the global area and 94 per cent of the global production of this crop. The production of groundnut is concentrated in Asia and Africa with 56 and 40 per cent of the global area and 68 and 25 per cent of the global production, respectively (Anon., 2008; Reddy et al., 2013).

In India, groundnut is grown over an area of 5.55 million hectares with a total production of 9.67 million tonnes and an average productivity of 1750 kg ha-1.

Its cultivation is mostly confined to southern states viz., Andhra Pradesh, Karnataka, Tamil Nadu and Maharashtra. The other important states, where it is grown are Gujarat, Madhya Pradesh, Rajasthan, Uttar Pradesh and Punjab. Among the major groundnut producing states in India during the year 2013-14, Gujarat is the largest groundnut producer (25 per cent), followed by Tamil Nadu (22.48 per cent), Andhra Pradesh (18.81 per cent), Karnataka (12.61 per cent) and Maharashtra (10.09 per cent). In area, Gujarat ranked first with 1.83 m ha, followed by Andhra Pradesh (1.38 m ha), Karnataka (0.65 m ha), Tamil Nadu (0.33 m ha) and Maharashtra (0.31 m ha), whereas in productivity, Tamil Nadu stood first with 2382 kg ha-1, followed by Gujarat (1603 kg ha-1), Maharashtra (1247 kg ha-1), Karnataka (705 kg ha-1) and Andhra Pradesh (650 kg ha-1) (Anon., 2014; Anon., 2015).

Engineering properties are useful and necessary in the design and operation of various farm equipments employed for agricultural operations (Sahay and Singh, 1994). The important engineering properties namely physical, mechanical, aerodynamic and frictional properties, which are directly related to the machine development, were determined in the present study. Basic information on these properties is of great importance and help for the engineers and scientists towards the equipment development and its efficient operation. The knowledge of engineering properties is important for design, development and efficient operation of thresher.

In recent years, many scientists have worked on the physical properties of some agricultural products, grains and fruits (Aydin and Ozcan, 2002; Baraye and Marigope, 2002; Cetin, 2007 and Yalcin et al., 2007). Also some physical properties of several varieties of groundnut pods and kernels have been studied by various researchers (Manjunath et al., 1998; Baryeh, 2001; Olajide and Igbeka, 2003; Maduako and Hamman, 2004; Aydin, 2007; Mpotokwane et al., 2008; Davies, 2009; Ghanem and Shetawy, 2009; Saeeid et al., 2009; Balasubramanian et al., 2011). Since the size and shape of many local varieties vary from each other, thus the physical properties of the groundnut pods are important for development of groundnut thresher, and hence this study was made to determine some important engineering properties of groundnut pods.

MATERIALS AND METHODS

Pods of six groundnut varieties *viz*., ICGV-00351, KADARI-9, R-8808, R-2001-2, R-2001-3 and TMV-2 were selected for determining the engineering properties. For all the experiments, the samples were collected from Research farm of University of Agricultural Sciences, Raichur, Karnataka, India. The pods were selected randomly from the bulk samples of each variety. The following engineering properties were determined by using standard procedure as explained below.

Physical Properties of Groundnut Pods

A specific knowledge of the physical properties of groundnut pods such as length, width, thickness, thousand pods weight, roundness, perimeter, geometric mean diameter, arithmetic mean diameter, sphericity, surface area, square mean diameter, equivalent diameter, aspect ratio, bulk density and pod-vine ratio is essential for design of threshing equipment in order to decide the cylinder speed, concave clearance, sieve sizes and seed drop mechanisms. The size and shape of pods were also important physical properties for separation of pods from the vine and foreign material. Hence, the physical properties of commonly grown six groundnut varieties *viz*., ICGV-00351, KADARI-9, R-8808, R-2001-2, R-

2001-3 and TMV-2 were determined by using standard procedure and techniques.

Dimensions of the Groundnut Pods

Fifty pods were randomly selected from the bulk sample in order to determine the size and shape of the pods. For each pod, three principal dimensions, namely length, width and thickness were measured using a vernier caliper with an accuracy of ± 0.01 mm (Aydin, 2007; Bamgboye and Adebayo, 2012).

Roundness

Roundness is a measure of the sharpness of the corners of solid materials. Fifty pods of groundnuts were randomly selected from the bulk sample. The roundness of irregular particle was determined by most widely accepted method (Sahay and Singh, 1994; Maduako and Hamman, 2004). The selected samples were opened along their line of symmetry (length wise) into two halves after measuring their lengths using vernier calipers. The shape of one-half of each sample at its natural rest position was traced on paper. The largest inscribed circle and the smallest circumscribing circle were constructed on each tracing paper and the diameters of both circles were noted. The area of the smallest circumscribing circle (A_c) was calculated and the largest projected area (A_p) of each sample was measured using a planimeter. Then the roundness was determined using the following expression;

$$\text{Roundness} = \frac{A_p}{A_c} \tag{1}$$

Where,

A_p = Largest projected area of groundnut pod in natural rest position, mm^2

A_c = Area of smallest circumscribing circle, mm^2

Sphericity

Sphericity (ϕ) may be defined as the ratio of the diameter of a sphere of the same volume as that of the particle and the diameter of the smallest circumscribing sphere or generally the largest diameter of the particle. This parameter shows the shape character of the particle relative to the sphere having same volume. The degree of sphericity (ϕ) was determined using following formula (Mohsenin 1986; Singh et al., 2010).

$$\phi = \frac{(L \times W \times T)^{1/3}}{L} \tag{2}$$

Where,

L = Length, mm

W = Width, mm

T = Thickness, mm

Arithmetic Mean Diameter (D_a) and Geometric Mean Diameter (D_g)

Axial dimensions, namely length (L), width (W) and thickness (T) for each variety of groundnut pods were

measured with a digital vernier caliber with an accuracy of ±0.01 mm. The average diameter was calculated by using the arithmetic mean and geometer means of the three axial dimensions. The arithmetic mean diameter (D_a) and geometric mean diameter (D_g) of the groundnut pods were calculated by using the following relationships (Mohsenin, 1986; Bahnasawy, 2007).

$$D_a = \frac{(L + W + T)}{3}, \text{mm} \tag{3}$$

$$D_g = (L + W + T)^{1/3}, \text{ mm} \tag{4}$$

Surface Area

Knowledge of surface area of some parts of plant materials such as leaf area and surface area of pods, are important to scientists and agricultural engineers for development of farm equipments. The surface area (S) of groundnut pod was determined by analogy with a sphere of the same geometric mean diameter, using the expression cited by Davies and Zibokere (2011), Jouki and Khazaei (2012).

$$S = \pi (D_g)^2, \text{ mm}^2 \tag{5}$$

Aspect Ratio

The aspect ratio (R) was calculated by applying the following relationship (Davies, 2009).

$$R = \frac{W}{L} \tag{6}$$

Where,

W = Width, mm

L = Length, mm

Thousand Pod Mass

The 1000 unit mass was determined using precision electronic balance with an accuracy of 0.01g. To evaluate the 1000 unit mass, 50 randomly selected samples were weighed and mean values were reported (Davies, 2009; Balasubramanian et al., 2011; Sharma et al., 2011).

Moisture Content

The moisture content of groundnut pods and vines were determined using the hot air oven method. The initial weights of samples were recorded using the electronic balance. Triplicate samples were dried in hot air oven set at temperature of 105°C ± 2 (ASAE, 1994) and monitored over a period of 24 hours at 6 hour intervals until the weights of the samples were found to be constant. The moisture content of groundnut pod and vine were calculated by using following relationship.

$$\text{Moisture content (\%)} = \frac{(W_1 - W_2)}{(W_1 - W_3)} \times 100 \tag{7}$$

Where,

W_1 = Weight of the wet sample, g

W_2 = Weight of the dry sample, g

W_3 = Weight of the moisture can, g

Bulk Density

The method reported by Maduako and Hamman (2004), Shkelqim and Joachim (2010) was adopted for bulk density determination. A 75 x 75 x 90 mm box was filled with groundnut pods and weighed using an electronic balance of 0.01g accuracy. The trials were repeated five times using different sets of pods for each variety and the bulk density was calculated from the following equation.

$$\rho_b = \frac{M}{V}, \text{ g cm}^{-3} \tag{8}$$

Where,

M = Mass of the pod sample, g

V = Volume of sampler, cm^3

Pod-Vine Ratio

Ten samples of groundnut pods with vine, each weighing about 1 kg were selected randomly from bulk sample and fully matured pods were removed from the vine. The weight of pod and vine were recorded separately using an electronic balance having 0.01g accuracy. The trials were replicated thrice for all the varieties and observations were recorded and average values were reported as the percentage of the mass of the pod to vine ratio.

Mechanical Properties of Groundnut Pods

Threshing of groundnut pod is an operation in which haulm failure is induced by tension or shear stress. The rheological properties of the pod and crop and its behaviour under different methods of force application would determine the effectiveness of threshing and damage to the pod in a mechanical device. The properties would also determine the energy requirement for threshing with a given mode and rate of load application.

With the above points in view, the structural characteristics of pod-vine system were studied by subjecting the pods and haulms to different forms of stresses. The structural properties are inter-related to moisture content and variety of pod.

Force of Attachment of Pod

The force required to separate the groundnut pod from plant is an important factor, which plays a major role in the design of groundnut thresher. The force required for separation should be just more than the force of attachment. The method reported by Chandio et al. (2013) was adopted to determine the cutting force required for separating the pod from vine. The cutting force was measured using a texture analyser (Plate 1) at a loading rate of 10 mm s^{-1}. The test set comprises of a blade with two locking screws. A central slot allows the free movement of the blade to limit friction during analysis.

Aerodynamic Properties of Groundnut Pod and Vine

The cleaning process in a thresher often uses air as a carrier for separating the desirable product from the unwanted materials. The air flow occurs around the solids and the problem involves the action of the forces exerted by the air on these solids. The behaviour of particles in an air stream is governed by their aerodynamic properties (Klenin et al., 1985). It becomes necessary to have knowledge of aerodynamic properties such as terminal velocity of the materials which is required for the design of air conveying systems and the separation equipment (Sahay and Singh, 1994).

Terminal Velocity

The terminal velocity of the particle may be defined as the air velocity at which a particle remains in suspended state in a vertical pipe. When air stream is used for separation of a product such as pods from its associated foreign materials, the knowledge of terminal velocity of all the particles involved would define the range of air velocities affecting good separation of the pods from foreign materials. For these reasons, terminal velocity has been used as important aerodynamic properties of materials in such applications as conveying and separation from foreign materials (Mohsenin, 1986).

In order to thresh the grains with stationary thresher and cleaning unit, it is important to know the aerodynamic property of grain and straw. By defining the terminal velocity of different threshed materials, it is possible to determine and set the maximum possible air velocity in which material other than grain can be removed without loss of grain (Zewdu, 2007).

The terminal velocity was measured using a test stand as shown in Plate 2. It consists of a vertical transparent glass tube of 450 mm long with a diameter of 60 mm, which was used to suspend the particles in an air stream. The air was supplied by a suction blower fan powered by an electric motor. The air pressure delivered from the fan was aspired via a pipe to the orifice plate through a throttle. The test was carried out by placing the sample on a mesh screen in vertical transparent glass tube. The fan discharge was increased manually until the particles were under suspension. The air velocity was measured at the top of vertical glass tube by using digital anemometer having a least count of 0.1 m s^{-1} and data was recorded (Sayed et al., 2001).

Frictional Properties of Groundnut Pod

The frictional properties such as angle of repose and coefficient of friction are important in designing of hoppers, chutes, pneumatic conveying systems, screw conveyors, forage harvesters, threshers *etc.* In mechanical and pneumatic conveying systems, the materials generally move or slides in direct contact with the trough, casing and other components of the machine. Thus, various parameters affect the power requirement to drive the machine. Among these parameters, the frictional losses are one of the factors which must be overcome by providing additional power to the machine. Hence, the knowledge of frictional properties of the agricultural materials is necessary; therefore, following frictional properties of the groundnut pods were determined as explained below.

Angle of Repose

The angle of repose is the angle between the base and the slope of the cone formed on a free vertical fall of the granular material to a horizontal plane. A tapering hopper (Plate 3) made of sheet metal with the top and bottom having a dimension of 300 x 300 mm and 100 x 100 mm, respectively and a height of 300 mm was used to measure the angle of

repose. At 200 mm from the top, a circular disc of 100 mm diameter was fixed so that enough gap was left between the hopper wall and disc which allows the pods to flow through during the test. A horizontal sliding gate was provided right below the disc for sudden release of the pods during the test. Similar method was used by (Nimkar and Chattopadhyay, 2001; Taser et al., 2005 and Razavi et al., 2007). While testing, pod was filled in the hopper and the horizontal sliding gate was suddenly opened. The height of seed piled on the circular disc was measured and used to calculate the angle of repose by using the formula;

$$\theta = \tan^{-1}\left(\frac{h_0}{r}\right) \tag{9}$$

Where,

θ = Angle of repose, degree

h_0 = Height of heap, m

r = Radius of heap, m

Static Coefficient of Friction

The static friction may be defined as the friction forces acting between surface of contact at rest with respect to each other. The coefficient of friction apparatus (Plate 4) consists of a horizontal plane and a bottomless open container and a pan. Known weights of pods were taken in the container. The weights were added in the pan and at the instant at which the pan weight exceeds the pods weight and friction; the container starts to slide on selected surface. The static coefficient of friction for groundnut pod was determined with respect to three test surfaces *viz*., plywood, MS sheet and wood by inclined surface method. The static coefficient of friction was calculated using the equation suggested by Sahay and Singh, 1994; Balasubramanian, 2001; Bahnasawy, 2007.

$$\mu = \frac{F}{N} \tag{10}$$

Where,

μ = Coefficient of friction

F = Frictional force (force applied)

N = Normal force (weight of the grain)

RESULTS AND DISCUSSIONS

The crop parameters and engineering properties of freshly harvested groundnut pod and vine were measured at a moisture content of 32.20-34.80 per cent (w.b) and 36.47-42.68 per cent (w.b), respectively.

Crop Parameters of Selected Groundnut Varieties

The general parameters of the groundnut varieties selected for the study are presented in Table 1. The mean height of plant and length of vine for all the varieties of groundnut crop were found to be 674.66 and 573.56 mm with a deviation

of 45.33 and 55.11 mm, respectively. To avoid much variation in linear dimensions of pods, the pods were selected from the bulk volume of each varieties were used for the study. It was also observed that the mean length, width and thickness of pods were found to be 22.61, 12.68 and 12.39 mm with a deviation of 1.37, 0.75 and 0.69 mm, respectively (Table 1). These values were in close agreement with the findings of Sayed et al. (2001) and Balasubramanian et al. (2011).

The number of pods per plant counted in plants of six varieties were analysed and the data was presented in Table 1. It was observed that maximum pods per plant were in TMV-2 (21.07) and minimum of 11.87 pods were in ICGV 00351 variety plants. The mean value was found to be 15.43 with a deviation of 3.31. The mean weight of thousand pods for all the varieties was found to be 1273.92 g with a deviation of 107.73 g (Table 1). Similar findings were reported by Sayed et al. (2001), Davies (2009) and Balasubramanian et al. (2011).

Engineering Properties of Selected Groundnut Varieties

In order to have flexibility in using the groundnut thresher, for different varieties of groundnut for reducing the variation in the output, the engineering properties of commonly grown six groundnut varieties *viz*., ICGV-00351, KADARI-9, R-8808, R-2001-2, R-2001-3 and TMV-2 were analysed and results are presented in Table 2 and discussed below.

Physical Properties of Groundnut Pods

The physical properties of groundnut pods *viz*., roundness, perimeter, arithmetic mean diameter, geometric mean diameter, sphericity, surface area, square mean diameter, equivalent diameter, aspect ratio, bulk density and pod-vine ratio were determined for six groundnut varieties and presented in Table 2.

It was observed that the roundness of pods varied from 0.68 to 0.76. The mean value of roundness for all the varieties of groundnut pods was found to be 0.72 with a standard deviation of 0.03 and coefficient of variation of 4.40 per cent. The perimeter was maximum (87.61 mm) for R-8808 and a minimum of 72.66 mm for TMV-2 with a standard deviation of 5.04 mm and coefficient of variation of 6.41 per cent. The arithmetic mean diameter of the pod was found to be in the range of 14.78 to 16.84 mm with a mean value of 15.89 mm. The maximum arithmetic mean diameter of 16.84 mm was recorded for R-2001-2 variety while it was minimum (14.78 mm) for KADARI-9 variety. The geometric mean diameter of all the varieties of groundnut pods was in the range of 13.86 to 15.72 mm with mean value of 14.82 mm. The similar results were reported by Baryeh (2001), Olajide and Igbeka (2003) and Maduaka and Hamman (2004).

The sphericity was maximum (0.71) for R-2001-3, while it was minimum (0.62) for ICGV 00351 with a mean value of 0.66 and standard deviation of 0.03. The surface area of pods was found to be maximum (778.43 mm^2) for R-2001-2 followed by R-2001-3 (735.75 mm^2) and a minimum of 605.26 mm^2 for KADARI-9 with standard deviation of 66.19 mm^2. It was also observed that the square mean diameter of the pods varied from 19.95 to 24.70 mm. The mean value of square mean diameter for all the varieties was found to be 22.13 mm with standard deviation of 1.62 mm and coefficient of variation of 7.32 per cent. The maximum equivalent diameter of 18.58 mm was observed for ICGV 00351 and a minimum of 16.41 mm for TMV-2 variety. The aspect ratio for all the varieties of pods was in the range of 0.94 to 0.99. The mean value of aspect ratio was found to be 0.96 with a deviation of 0.01. The results are in agreement with the findings of Saeeid et al. (2009) and Balasubramanian et al. (2011).

The mean bulk density of all the varieties was found to be 0.26 g cm^{-3}. The maximum bulk density of 0.27 g cm^{-3} was found for KADARI-9 while it was minimum (0.25 g cm^{-3}) for R-2001-3 variety. The mean value of pod-vine ratio for

six groundnut varieties was found to be 3.59 with a standard deviation of 0.13 and coefficient of variation of 3.58 per cent which are close agreement with the values reported by Aydin (2007).

Mechanical Properties of Groundnut Pods

The force required to detach the pod from plant is a measure of the stripping force required for separating the pod. The force of attachment of pod was measured using the standard tests and procedures as explained in previous section and results are tabulated in Table 3.

It was observed that the mean value of force required to detach the pod from vine was maximum (6.15 kg) for KADARI-9, while it was minimum (2.6 kg) for TMV-2 variety at an average moisture content of 39.48 per cent. The standard deviation and coefficient of variation were found to be 1.37 kg and 30.67 per cent, respectively. Similar findings were reported by Chandio et al. (2013).

Aerodynamic Properties of Groundnut Pod and Vine

The terminal velocity of groundnut pod and vine in a vertical air stream were measured and the corresponding values observed were statistically analyzed and presented in Table 4. It was noticed that little variation was evident among the different varieties under study. The terminal velocity of groundnut pod was maximum (10.20 m s^{-1}) for KADARI-9 variety followed by R-2001-3 (9.12 m s^{-1}), R-2001-2 (8.84 m s^{-1}), TMV-2 (8.78 m s^{-1}), R-8808 (8.04 m s^{-1}), whereas it was minimum for variety ICGV 00351 (7.42 m s^{-1}). The mean value was found to be 8.73 m s^{-1} with a standard deviation of 0.95 m s^{-1}. The terminal velocity of groundnut vine varied from 3.38 to 4.46 m s^{-1} in the moisture range of 36.47 to 42.68 per cent with a mean value of 3.91 m s^{-1} and standard deviation of 0.45 m s^{-1}. The results are in agreement with the findings of Sayed et al. (2001) and Ghanem and Shetaway (2009).

Frictional Properties of Groundnut Pod

The frictional properties of groundnut pods of different varieties *viz.,* ICGV-00351, KADARI-9, R-8808, R-2001-2, R-2001-3 and TMV-2 were analyzed and presented in Table 5. The angle of repose of groundnut pods ranged from 26.36° in TMV-2 to 29.09° in R-8808. The mean value for all the varieties was found to be 27.45° with a deviation of 1.01° and coefficient of variation of 3.64 per cent. The coefficient of friction of the pods for the selected varieties ranged from 0.52 to 0.58 on plywood, 0.36 to 0.42 on MS sheet and 0.58 to 0.65 on wood. The mean value of coefficient of friction was found to be maximum (0.62) on wood, whereas it was minimum (0.40) on MS sheet. The standard deviation and coefficient of friction ranged from 0.023 to 0.026 and 4.03 to 5.38 per cent, respectively. The similar results were reported by Olajide and Igbeka (2003) and Mptokwane et al. (2008).

CONCLUSIONS

In this study, the engineering properties of freshly harvested groundnut varieties were determined. The results indicated that the geometric mean, arithmetic mean, square mean and equivalent diameter were found to be 14.82, 15.89, 22.13 and 17.62 mm, respectively with an average bulk density of 0.26 g cm^{-3}. The computed mean value of roundness and perimeter were found to be 0.72 and 78.53 mm. The sphericity and surface area of all the varieties were in the rage of 0.62 to 0.71 and 605.26 to 778.43 mm^2 with a mean value of 0.66 and 692.69 mm^2, respectively. The mean value of pod-vine ratio for six groundnut varieties was found to be 3.59. The results also showed that groundnut pods were neither round nor spherical, but may be oblong in shape. It was observed that the mean value of force required to detach the pod from vine

was found to be 4.28 kg. The terminal velocity of groundnut pod and vine were found to be 8.73 and 3.91 m s^{-1}. The angle of repose of groundnut pods ranged from 26.36° for TMV-2 to 29.09° for R-8808. The mean values of coefficient of friction of the groundnut pods for the selected varieties on plywood, MS sheet and wood were found to be 0.559, 0.406 and 0.623, respectively. The engineering properties determined could be used as yard stick for deciding the operational parameters in designing the groundnut thresher.

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AUTHOR CONTRIBUTIONS

Mr. Manjunatha, K was the Ph.D. Scholar who conducted the experiment. Dr. M. Anantachar guided the Ph.D. Scholar and edited the manuscript. Dr. M. Veerangouda, Dr. K. V. Prakash, Dr. B. K. Desai and Dr. S. N. Vasudevan were the members of advisory committee.

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Table 1: Crop Parameters of Groundnut Varieties Selected for the Study

Particulars	ICGV 00351	KADARI-9	R-8808	R-2001-2	R-2001-3	TMV-2	Min.	Max.	Mean Value	SD	CV
Height of plant, mm	669.60	615.47	639.67	725.60	669.13	728.47	615.47	728.47	674.66	45.33	6.72
Length of vine, mm	553.00	521.13	509.73	630.80	585.93	640.73	509.73	640.73	573.56	55.11	9.61
Length of pod (L), mm	24.01	20.67	23.47	23.89	21.59	22.05	20.67	24.01	22.61	1.37	6.07
Width of pod (W), mm	12.35	11.95	12.81	13.51	13.58	11.86	11.86	13.58	12.68	0.75	5.94
Thickness of pod (T), mm	12.11	11.71	12.43	13.11	13.29	11.67	11.67	13.29	12.39	0.69	5.59
Number of pods per plant, No.	11.87	16.53	16.27	13.07	13.80	21.07	11.87	21.07	15.43	3.31	21.42
Hundred pods weight, g	109.80	118.07	116.93	115.73	110.60	120.33	109.80	120.33	115.24	4.20	3.64
Thousand pods weight, g	1320.27	1292.93	1281.87	1301.73	1065.93	1380.80	1065.93	1380.80	1273.92	107.73	8.46
Moisture content of pod, %	32.20	34.80	32.36	32.91	33.60	33.47	32.20	34.80	33.22	0.96	2.88
Moisture content of vine, %	36.47	41.01	42.68	38.65	38.99	39.06	36.47	42.68	39.48	2.13	5.40

Table 2: Physical Properties of Selected Groundnut Varieties

Particulars	ICGV 00351	KADARI-9	R-8808	R-2001-2	R-2001-3	TMV-2	Min.	Max.	Mean Value	SD	CV
Roundness	0.75	0.74	0.68	0.72	0.70	0.76	0.68	0.76	0.72	0.03	4.40
Perimeter, mm	80.06	76.88	87.61	76.74	77.22	72.66	72.66	87.61	78.53	5.04	6.41
Arithmetic mean diameter (Da), mm	16.16	14.78	16.24	16.84	16.15	15.19	14.78	16.84	15.89	0.76	4.77
Geometric mean diameter (Dg), mm	14.88	13.86	15.09	15.72	15.30	14.09	13.86	15.72	14.82	0.72	4.84
Sphericity (□)	0.623	0.674	0.644	0.660	0.710	0.644	0.62	0.71	0.66	0.03	4.57
Surface area, mm^2	696.41	605.26	715.04	778.43	735.75	625.26	605.26	778.43	692.69	66.19	9.56
Square mean diameter, mm	24.70	22.70	20.96	22.35	22.14	19.95	19.95	24.70	22.13	1.62	7.32
Equivalent diameter, mm	18.58	17.11	17.43	18.30	17.86	16.41	16.41	18.58	17.62	0.80	4.54
Aspect ratio	0.990	0.965	0.951	0.959	0.943	0.956	0.943	0.990	0.96	0.016	1.70
Bulk density of pod (β), g cm^{-3}	0.271	0.277	0.269	0.268	0.252	0.274	0.252	0.277	0.26	0.008	3.146
Pod-vine ratio	3.50	3.62	3.70	3.51	3.75	3.42	3.42	3.75	3.59	0.13	3.58

Table 3: Mechanical Properties of Groundnut Varieties Selected for the Study

Particulars	ICGV 00351	KADARI - 9	R - 8808	R-2001-2	R-2001-3	TMV-2	Min.	Max.	Mean Value	SD	CV
Force of attachment of pod, g	5353.84	6157.48	3584.64	3467.24	4548.68	2619.60	2619.60	6157.48	4288.58	1315.35	30.67

Table 4: Aerodynamic Properties of Groundnut Varieties Selected for the Study

Particulars	ICGV 00351	KADARI - 9	R - 8808	R-2001-2	R-2001-3	TMV - 2	Min.	Max.	Mean Value	SD	CV
Terminal Velocity (M S^{-1})											
Pod	7.42	10.20	8.04	8.84	9.12	8.78	7.42	10.20	8.73	0.95	10.89
Vine	3.38	4.4	4.46	3.6	3.6	4.02	3.38	4.46	3.91	0.45	11.60

Table 5: Frictional Properties of Groundnut Varieties Selected for the Study

Particulars	ICGV 00351	KADARI-9	R-8808	R-2001-2	R-2001-3	TMV - 2	Min.	Max.	Mean Value	SD	CV
Angle of repose (□□□□degree	28.128	27.375	29.092	26.728	27.071	26.360	26.360	29.092	27.459	1.010	3.64
Coefficient Of Friction											
Plywood	0.560	0.552	0.588	0.561	0.570	0.520	0.520	0.588	0.559	0.023	4.037
MS sheet	0.408	0.402	0.425	0.408	0.426	0.366	0.366	0.426	0.406	0.022	5.383
Wood	0.619	0.620	0.658	0.615	0.644	0.584	0.584	0.658	0.623	0.026	4.101

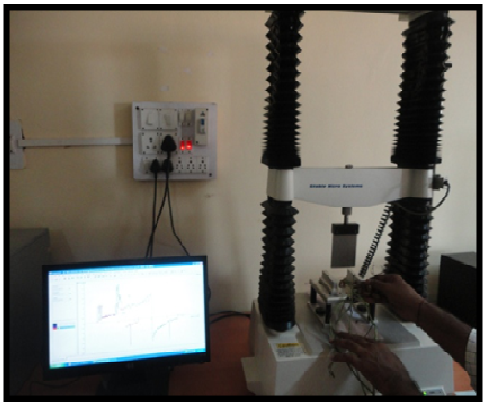

Plate 1: A View of Texture Analyser Used to Measure the Cutting Force Required to Separate the Pod from Vine

Plate 2: Test Stand for the Measurement of the Terminal Velocity of Pod And Vine

Plate 3: A View of Angle of Reponse Apparatus Used for the Study

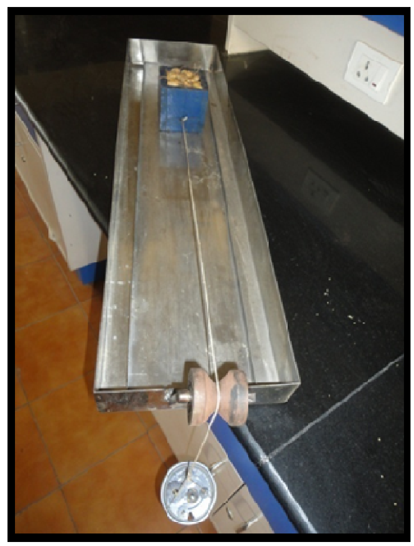

Plate 4: Coefficient of Friction Measured on MS Sheet